COURSE TITLE: ELECTRICAL SYSTEM COMPOENTS

Lesson 1: SWITCHGEARS

I.1-Fundamental of Power Systems Protection

The purpose of an Electric Power System is to generate and supply electrical energy to consumers. The power system should be designed and managed to deliver this energy to the utilization points with both reliability and economically

The capital investment involved in power system for the generation, transmission and distribution is so great that the proper precautions must be taken to ensure that the equipment not only operates as nearly as possible to peak efficiency, but also must be protected from accidents

The normal path of the electric current is from the power source through copper (or aluminium) conductors in generators, transformers and transmission lines to the load and it is confined to this path by insulation. The insulation, however, may break down, either by the effect of temperature and age or by a physical accident, so that the current then follows an abnormal path generally known as Short Circuit or Fault

• Any abnormal operating state of a power system is known as FAULT. Faults in general consist of short circuits as well as open circuits. Open circuit faults are less frequent than short circuit faults, and often they are transformed in to short circuits by subsequent events.

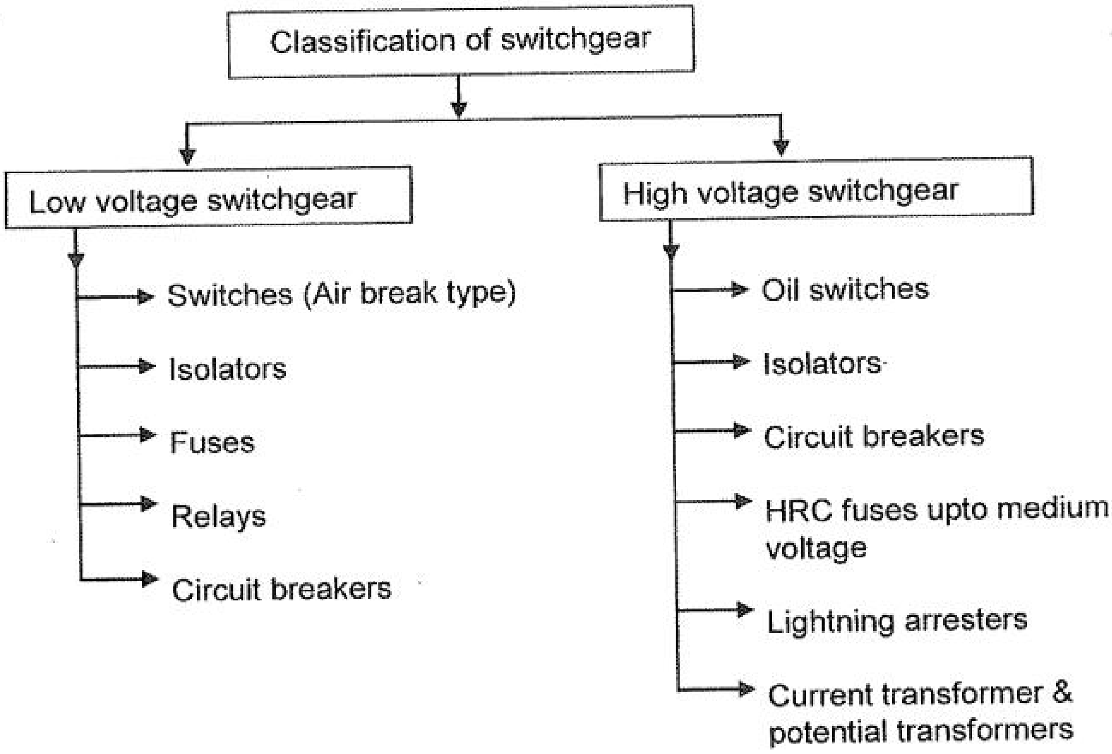


Figure1: Classification of Switchgear

I.2- Consequences of occurrence of Faults

Faults are of two type

- Short circuit fault- current
- Open circuit fault- voltage

In terms of seriousness of consequences of a fault , short circuits are of far greater concern than open circuits, although some open circuits present some potential hazards to personnel Classification of short circuited Faults

- Three phase faults (with or without earth connection)
- Two phase faults (with or without earth connection)
- Single phase to earth faults

Classification of Open Circuit Faults

- Single Phase open Circuit
- Two phase open circuit
- Three phase open circuit

Consequences

- Damage to the equipment due to abnormally large and unbalanced currents and low voltages produced by the short circuits

• Explosions may occur in the equipments which have insulating oil, particularly during short circuits. This may result in fire and hazardous conditions to personnel and equipments

• Individual generators with reduced voltage in a power station or a group of generators operating at low voltage may lead to loss of synchronism, subsequently resulting in islanding.

• Risk of synchronous motors in large industrial premises falling out of step and tripping out.

The general layout of a protection system may be viewed as given in the following figure

The general layout of a protection system may be viewed as given in the following figure

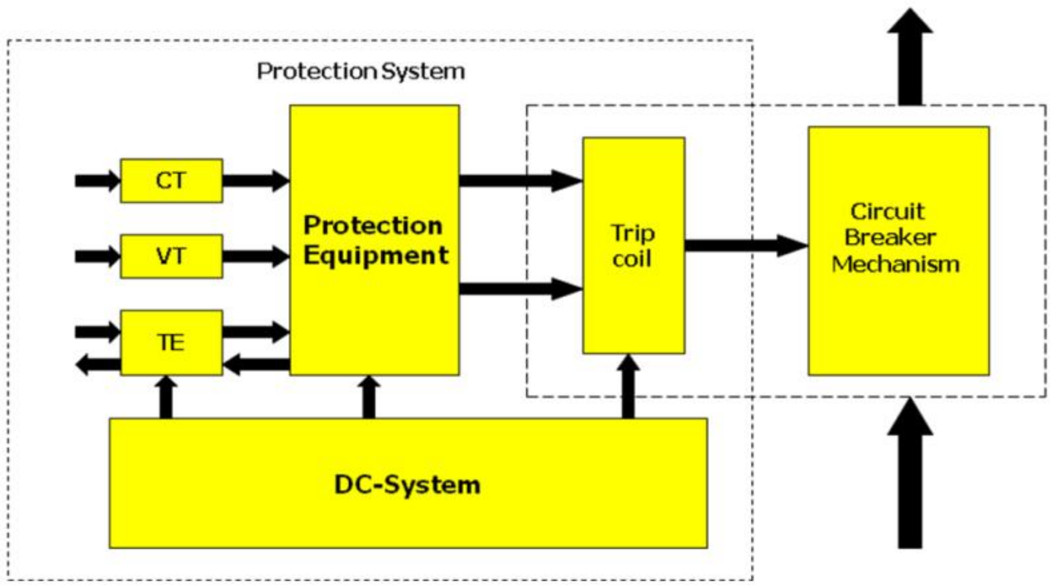


Figure2: Protection System

I.3-Zones and types of Protection System

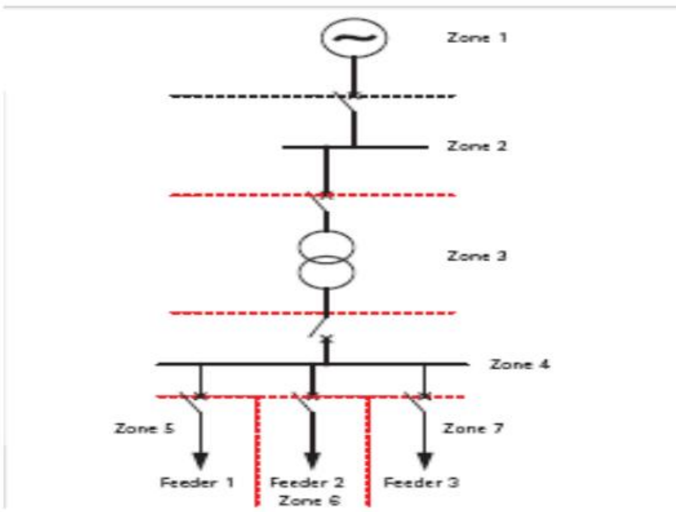
I.3.1-Zones of Protection system

An electric power system is divided into several zones of protection. Each zone of protection, contains one or more components of a power system in addition to two circuit breakers.

• When a fault occurs within the boundary of a particular zone, then the protection system responsible for the protection of the zone acts to isolate (by tripping the Circuit Breakers) every equipment within that zone from the rest of the system.

• The circuit Breakers are inserted between the component of the zone and the rest of the power system. Thus, the location of the circuit breaker helps to define the boundaries of the zones of protection.

• Different neighbouring zones of protection are made to overlap each other, which ensure that no part of the power system remains without protection. However, occurrence of the fault with in the overlapped region will initiate a tripping sequence of different circuit breakers so that the minimum necessary to disconnect the faulty element.



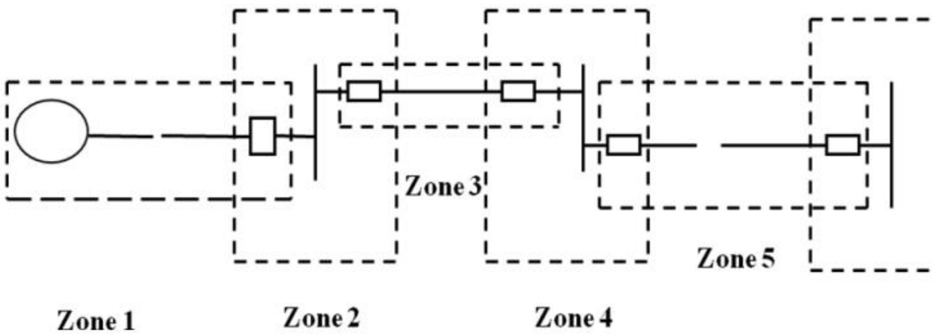


Figure3: Level of Protection

I.3.2- Types of Protection (Primary and Back-up protection)

I.3.2.1- Primary protection

The primary protection scheme ensures fast and selective clearing of any fault within the boundaries of the circuit element, that the zone is required to protect. Primary Protection as a rule is provided for each section of an electrical installation.

However, the primary protection may fail. The primary cause of failure of the Primary Protection system are enumerated below.

1. Current or voltage supply to the relay.
2. D.C. tripping voltage supply
3. Protective relays
4. Tripping circuit
5. Circuit Breaker

I.3.2.2- Back-up protection

Back-up protection is the name given to a protection which backs the primary protection whenever the later fails in operation. The back-up protection by definition is slower than the primary protection system. The design of the back-up protection needs to be coordinated with the design of the primary protection and essentially it is the second line of defence after the primary protection system.

I.4- Protection system requirements and some basic terminologies used

The fundamental requirements for a protection system are as follows:

I.4.1- Reliablity

It is the ability of the protection system to operate correctly. The reliability feature has two basic elements, which are dependability and security. The dependability feature demands the certainty of a correct operation of the designed system, on occurrence of any fault. Similarly, the security feature can be defined as the ability of the designed system to avoid incorrect operation during faults. A comprehensive statistical method based reliability study is required before the protection system may be commissioned. The factors which affect this feature of any protection system depends on some of the following few factors.

a) Quality of Component used
b) Maintenance schedule
c) The supply and availability of spare parts and stocks
d) The design principle
e) Electrical and mechanical stress to which the protected part of the system is subjected to.

I.4.2- Speed

Minimum operating time to clear a fault in order to avoid damage to equipment. The speed of the protection system consists primarily of two time intervals of interest.

a) The Relay Time : This is the time between the instant of occurrence of the fault to the instant at which the relay contacts open.

b) The Breaker Time: This is the time between the instant of closing of relay contacts to the instant of final arc extinction inside the medium and removal of the fault.

I.4.3- Selectivity

This feature aims at maintaining the continuity of supply system by disconnecting the minimum section of the network necessary to isolate the fault. The property of selective tripping is also known as "discrimination". This is the reason for which the entire system is divided into several protective zones so that minimum protion of network is isolated with accuracy. Two examples of utilization of this feature in a relaying scheme are as follows

a) Time graded systems

b) Unit systems

I.4.4- Sensitivity

The sensitivity of a relay refers to the smallest value of the actuating quantity at which the relay operates detecting any abnormal condition. In case of an overcurrent relay, mathematically this can be defined as the ratio between the short circuit fault current (I) and the relay operating current (I). The value of I , should not be too small or large so that the relay is either too sensitive or slow in responding.

I.4.5- Stability

It is the quality of any protection system to remain stable within a set of defined operating scenarios and procedures. For example the biased differential scheme of differential protection is more stable towards switching transients compared to the more simple and basic Merz Price scheme in differential protection.

I.4.6- Adequacy

It is economically unviable to have a 100% protection of the entire system in concern. Therefore, the cost of the designed protection system varies with the criticality and importance of the protected zone. The protection system for more critical portions
is generally costly, as all the features of a good protection system is maximized here. But a small motor can be protected by a simple thermally operated relay, which is simple and cheap. Therefore, the cost of the protection system should be adequate in its cost.

I.4.7- Some basic terminologies used in protection system

Some basic terminologies commonly used in the protection system are enlisted below.

i) Measuring Relay ii) Fault Clearing Time iii) Auxilliary relay iv) Relay Time v) Pick up value vi) Reset Value vii) Drop out viii) Reach (under and over reaches) ix) Relay Burden x) Unit/ Non unit protection xi) All or Nothing relay.

I.5- Classification and construction of relays

I.5.1 Classification

Protection relays can be primarily classified in accordance with their construction, the actuating signal and application and function.

I.5.1.1 According to the Construction principle

Depending upon the principle of construction, the following four brad categories are found.

- Electromechanical
- Solid State
- Microprocessor
- Numerical

I.5.1.2 According to the actuating signals

The actuating signal may be any of the following signals including a numbers of different combinations of these signals depending upon whether the designed relay require a single or multiple inputs for its realization.

Current

- Voltage
- Power
- Frequency
- Temperature
- Pressure
- Speed
- Others

I.5.1.3 Function

The functions for which the protection system is designed classify the relays in the following few categories.

- Directional Over current
- Distance Over voltage
- Differential
- Reverse Power
- Others

It is important to notice that the same set of input actuating signals may be utilized to design to relays having different function or application. For example, the voltage and current input relays can be designed both as a Distance and/ or a Reverse Power relay.

Electromechanical relays

These relays are constructed with electrical, magnetic & mechanical components & have an operating coil & various contacts,& are very robust & reliable. Based on the construction, characteristics, these are classified in three groups.

Attraction relays

Attraction relays can be AC & DC and operate by the movement of a piece of iron when it is attracted by the magnetic field produced by a coil. There are two main types of relays:

1. The attracted armature type
2. Solenoid type relay

Attracted armature relays

- Consists of a bar or plate (made of iron) that pivots when it is attracted towards the coil.
- The armature carries the moving part of the contact ,which is closed or opened, according to the design, when the armature is attracted to the coil.

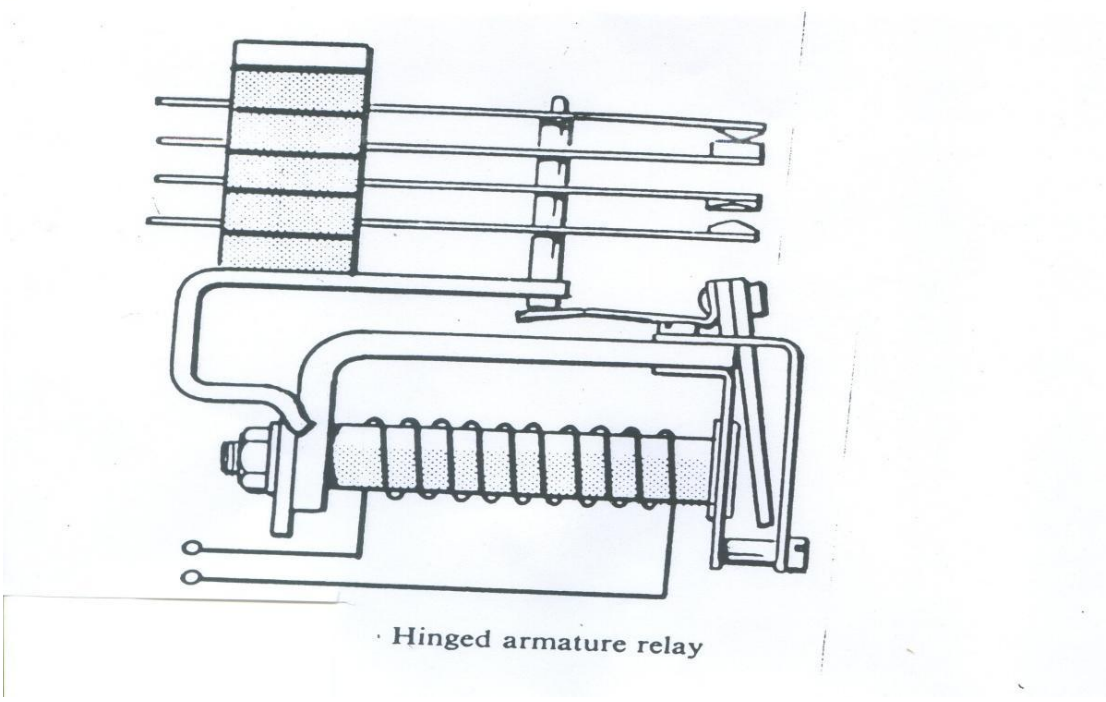


Figure4: Attracted armature relay

Solenoid type relays

In this a plunger or a piston is attracted axially within the field of the solenoid. In this case, the piston carries the moving contacts.

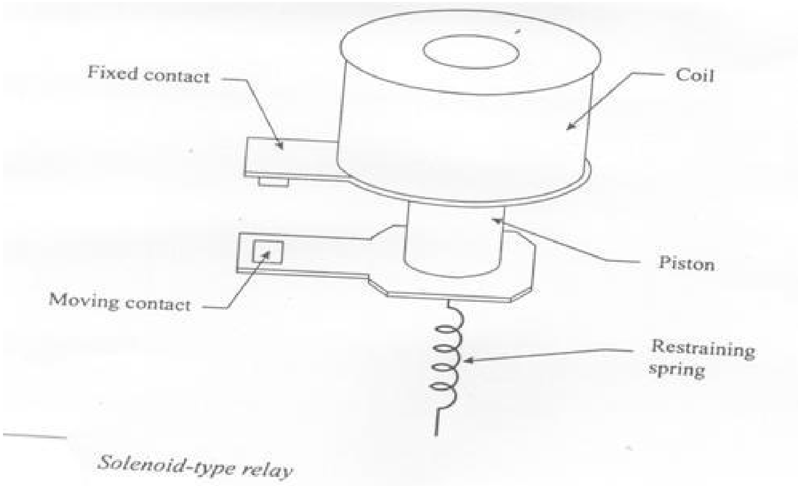


Figure5: Solenoid type relay

The force of attraction = $K_1 I^2 - K_2$

Where, K1 depends on

- The number of turns of the coil
- The air gap
- The effective area
- The reluctance of the magnetic circuit

K2 is the restraining force, usually produced by spring

For threshold or balanced condition, the resultant force is zero.

$K_1 I^2 = K_2$ $\quad$ $I = \sqrt{(\frac{K_2}{K_1})}$

In order to control the value of current at which relay operates, the parameters K_1 and K_2 may adjusted. Attraction relays effectively have no time delay and are widely used when instantaneous operation is required.

Relays with movable coils

This type of relay consists of a rotating movement with a small coil suspended or pivoted with the freedom to rotate between the poles of a permanent magnet. The coil is restrained by two special springs which also serve as connections to carry the current to the coil.

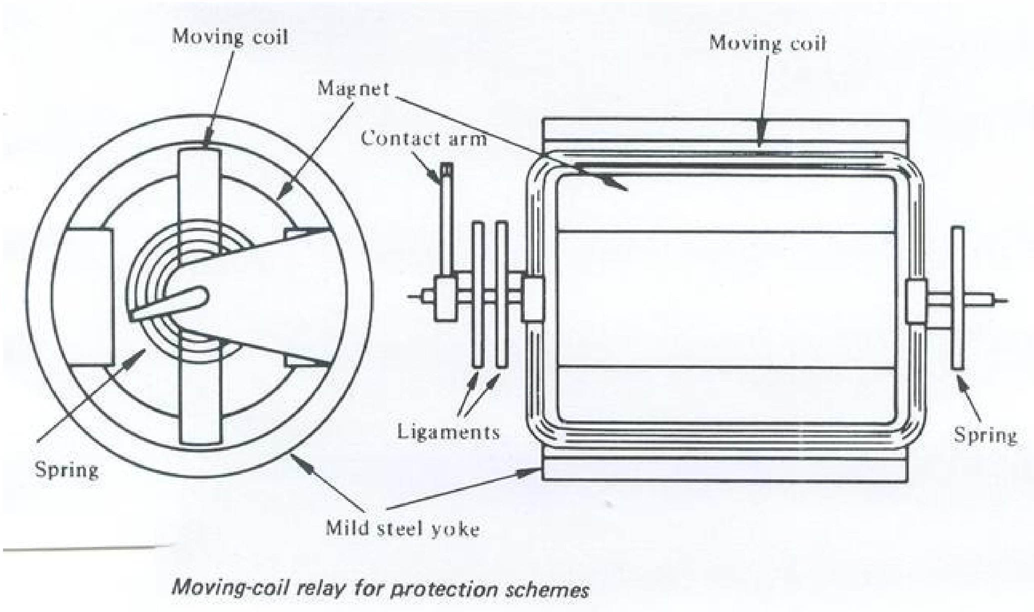


Figure6: Relay with movable coil

I.6- Overcurrent relays

- Protection against excess current was naturally the earliest protection systems to evolve
- From this basic principle has been evolved the graded over current system, a discriminate fault protection.
- “over current” protection is different from “over load protection”.
- Overload protection makes use of relays that operate in a time related in some degree to the thermal capability of the plant to be protected.
- Over current protection, on the other hand, is directed entirely to the clearance of the faults, although with the settings usually adopted some measure of overload protection is obtained.
- In terms of the general torque equation the over current relay has both constants K_2 and K_3 equal to zero. Therefore, the equation becomes